ADVANCED QUANTUM TECHNOLOGIES
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Quantum Micro–Nano Devices Fabricated in Diamond by Femtosecond Laser and Ion Irradiation

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Diamond has attracted great interest as a quantum technology platform thanks to its optically active nitrogen vacancy (NV) center. The NV's ground state spin can be read out optically, exhibiting long spin coherence times of ≈1 ms even at ambient temperatures. In addition, the energy levels of the NV are sensitive to external fields. These properties make NVs attractive as a scalable platform for efficient nanoscale resolution sensing based on electron spins and for quantum information systems. Diamond photonics enhance optical interactions with NVs, beneficial for both quantum sensing and information. Diamond is also compelling for microfluidic applications due to its outstanding biocompatibility, with sensing functionality provided by NVs. However, it remains a significant challenge to fabricate photonics, NVs, and microfluidics in diamond. In this Progress Report, an overview is provided of ion irradiation and femtosecond laser writing, two promising fabrication methods for diamond-based quantum technological devices. The unique capabilities of both techniques are described, and the most important fabrication results of color center, optical waveguide, and microfluidics in diamond are reported, with an emphasis on integrated devices aiming toward high performance quantum sensors and quantum information systems of tomorrow.

1. Introduction

Diamond has established itself as an important material system for quantum photonics due to the existence of stable and coherent fluorescent and spin active color centers such as the nitrogen vacancy (NV) center which can be utilized as a single photon source and as a solid-state qubit with long spin coherence time allowing for example long distance entanglement.[1] The biocompatibility of diamond,[2] and the possibility to use high density ensembles of the same color centers as room temperature quantum enabled sensors[3,4] presents exciting possibilities for life science microscopy and microfluidic applications. However, to harness diamond's strengths it is essential to have the ability to create micro and nano structures such as waveguides to guide and manipulate light to link together distant NV centers; to generate single or high density ensembles of color centers on demand; and to selectively etch micro channels to enable microfluidic lab-on-chip functionalities in diamond.

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The ORCID identification number(s) for the author(s) of this article can be found under https://doi.org/10.1002/qute.201900006

DOI: 10.1002/qute.201900006

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